CASE STUDIES: A NEW APPROACH TO TEACHING PLANT SYSTEMATICS

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The teaching of plant systematics is difficult at best. Because of the broad scope of the subject matter, one of the major problems is deciding exactly what types of information to include and what to ignore. The available options range from a very descriptive approach emphasizing familial, generic, and/or specific recognition to a perspective heavily laced with evolutionary theory and slanted toward experimental systematics or biosystematics. Somewhere between these two extremes lies the majority of existing courses in plant systematics, with the exact emphasis depending upon the interests and background of the professor involved.

Whatever the approach used in teaching plant systematics, in most cases little opportunity is available for the students to learn to make taxonomic decisions. Conspicuously lacking is some format or set of exercises for the student to apply his new understanding of how to assess variation with classical and/or experimental methods. He comes to know well the ways to go about gathering data from plants, but he lacks the experience and confidence to make sound taxonomic judgments.

Such a deficiency in students completing my own course in "Experimental Taxonomy" has been embarassingly apparent (to me as well as to the students) on the final examinations, in which I usually include a hypothetical set of morphological, cytological, and chemical data and ask the students to evaluate these for their taxonomic significance in the particular case study. The students performed poorly, and they raised the question of why this same type of exercise wasn't given to them throughout the course?

As a result of this student criticism, I have developed over the past few years a set of exercises that are designed to help the student gain confidence and proficiency in evaluating comparative data and in making taxonomic decisions. These exercises, or "case studies," are taken from recent systematic literature and are chosen to reflect different taxonomic problems as well as different types of comparative data. It is from the belief that the case study method has proven valuable in my own classes that I offer the following commentary for general appraisal. The purpose of the present paper, therefore, is: (1) to describe in detail exactly what a case study is; (2) to suggest possibilities for effective use of the case studies in the classroom; and (3) to comment on the beneficial results of using case studies, as judged from my own experience.

SIDA 7(2): 107—117. 1977.

DESCRIPTION OF A CASE STUDY

The way in which case studies are structured relates directly to the two main learning objectives for the students: (1) they should be able to recognize discontinuities in sets of comparative data, whether morphological, cytological, chemical, etc: and (2) they should be able to evaluate these observed discontinuities with respect to the various categories or ranks in the taxonomic hierarchy. Other secondary objectives prevail, such as the demonstration of confidence in making decisions and defending viewpoints, but these aspects will be discussed later.

The particular case studies are selected with two criteria in mind: (1) the papers should contain different types of data which should be displayed in different ways, such as in bar graphs, scatter diagrams, and histograms; and (2) the data presented must be displayed in such a way that taxonomic decisions can be made from these figures and tables alone. The first criterion is emphasized to give the student as much practice as possible with handling and interpreting different types of data. The second criterion is necessary so that the students may work on the comparative data themselves without relying on the author's biased discussion. Papers are not desirable, therefore, that treat stimulating problems but have only limited amounts of displayed data. The studies selected need not all be excellent from the standpoint of data-gathering or interpretation either; those with deficiencies also can be used pedagogically to good effect.

The case study is divided into four sections: (1) statement of the problem; (2) materials and methods; (3) data; and (4) abbreviated reference. The first section, the statement of the problem, indicates approximately at what taxonomic level the study focuses. For example, it would be necessary for the student to know that the problem at hand deals with infraspecific rather than intergeneric delimitation. If some guidelines are not given on the approximate rank involved, especially early in the course, the students sometimes approach the problem from very different perspectives. This often results in generating more confusion than understanding. The second section on materials and methods is believed necessary so that the students may see how the comparative data have been gathered (the laboratory of the course may be oriented this way if so desired) and so that they may evaluate critically the appropriateness of the methods for the situation at hand. In most papers the section on methods is set off by itself, which allows for easy removal from the paper proper; in other papers this information must be extracted from the introductory remarks or from the discussion. The third section of the case study contains the data, which are the most important part of the exercise because they serve as the basis for making the taxonomic decisions. As the author usually arranges the data in tables and/or figures to suggest the relationships as he views them, it is useful to scramble the data as presented and give unsuggestive labels to the initial groups, such as Taxon A, Taxon B, Taxon C, etc. In this way the student does not become prejudiced toward the author's viewpoint. The fourth and final section of the case study includes the abbreviated reference of the paper from which the data were taken. The title is omitted deliberately, because often it can give clues to the rank of the taxa involved or other suggestions that might bias the student.

To give a better idea of what constitutes a case study, an example is included below. It is important to remember that this is only one example from out of hundreds that could have been selected; it is also a relatively simple exercise. Some case studies, especially those involving cytogenetic data, can be very complex, but they are long and space limitations prohibit their inclusion here.

1. *Problem:* Provide a classification for the following taxa (A-D) using any or all of the following categories: genus, species, subspecies, variety, and form.

2. *Materials and Methods:* The taxa under study have been collected rather sparingly. Specimens borrowed from 12 herbaria yielded a total of only 72 collections. This material was supplemented by field observations and mass collections from 13 populations (Fig. 1).

Buds collected in the field for chromosomal studies were fixed in a modified Carnoy's solution (4 parts chloroform: 3 parts absolute alcohol: 1 part glacial acetic acid) and refrigerated immediately. They were transferred after 24 hours to 70% ethyl alcohol "colored" with iron acetate and left under refrigeration until squashes were made some months later. An aceto-orcein stain (0.5% orcein in a solution of 1 part glacial acetic acid: 1 part lactic acid: 1 part water) was employed. Mitotic counts were made from germinating seeds following colchicine treatment.

A single count of $n = 12$ for Taxon B has been reported by Raven & Kyhos (1961, Amer. J. Bot. 48:842). This was corroborated here by both meiotic and mitotic counts for plants in population 698. Meiotic counts of $n = 12$ were obtained for populations 700, 703, and 705, all of these being referable to Taxon A (Fig. 5). Meiosis was regular in all pollen cells examined except for occasional bridges at first anaphase in population 703. Bivalents ordinarily formed two terminalized chiasmata at late diakinesis.

After thorough morphologic investigation of all 13 populations surveyed in this study, certain characteristics of stems and leaves were found to be of greater diagnostic value than others in rendering taxonomic judgments. Figure 15 presents quantitative measurements of these characters. For these data a minimum of 20 individuals from each population was measured. One typical lower leaf per stem was used for blade width, length, and length/width measurements. The total upper surface of these leaves was examined with care in order to determine the minimum and maximum trichome lengths. The single longest leaf per individual stem was utilized for maximum leaf length, and stem heights were accounted for in attempting to evaluate the variation in the size of the plants. Table 1 supplements the data presented in Fig. 15. In it is summarized the remaining most significant morphologic variation that was found.

3. *Data:* Figs. 1-15; Table 1.

4. *Reference:* Ellison, W. L. 1971. Brittonia 23: 269-279.

EMPLOYMENT OF CASE STUDIES IN THE CLASSROOM

Before the case studies can be used effectively in the classroom, an introduction to concepts of taxonomy and classification (including grouping and ranking) must be presented. If the students have not already learned operational definitions for recognizing taxa and their subsequent ranking, they will not be able to work the case studies. In addition, some introduction to different types of data-gathering and display techniques is recommended. Only in this manner can the student begin to make progress in the critical evaluation of the data included in the case studies. Some considerable attention, therefore, must be given to the introduction of these several aspects of taxonomy before assigning the case studies to the class.

I have found it helpful to begin working first with the students on case study *examples*. These are structured exactly as the exercises described earlier in this paper, but a fifth section is added containing a discussion of the problem and a tentative classification, either drafted by the professor or extracted from the paper itself. In this way the students can check their own classifications against the one provided. When the students have mastered the examples, then they are ready to begin the exercises.

A number of mechanisms might be used for actually presenting the case study exercises to the students, but I have found the following sequence workable. An exercise is assigned to the class on one day with the announced intent of discussing the classifications on another day. At that time, the students are asked to describe their systems, usually accompanied by outlines on the blackboard, for the benefit of and discussion by the rest of the class. If the class is large, time may preclude having every person present his or her classification, but ideally everyone should have the opportunity. After discussion of the individual classifications, with particular emphasis on the prevailing similarities and differences, the professor can present his own and the author's views. Finally, the original paper can be put on library reserve or other accessible location for additional study by the students at their convenience.

BENEFICIAL RESULTS OF USING CASE STUDIES

In my own experience of teaching plant systematics with case studies, I have noticed several beneficial results that accrue to the students. It is realized that the observations to follow have not been quantified or experimentally verified in any way; they are simply syntheses of feedback from students on formal and informal course evaluations both before and after using case studies. It is believed, however, that the benefits mentioned are real.

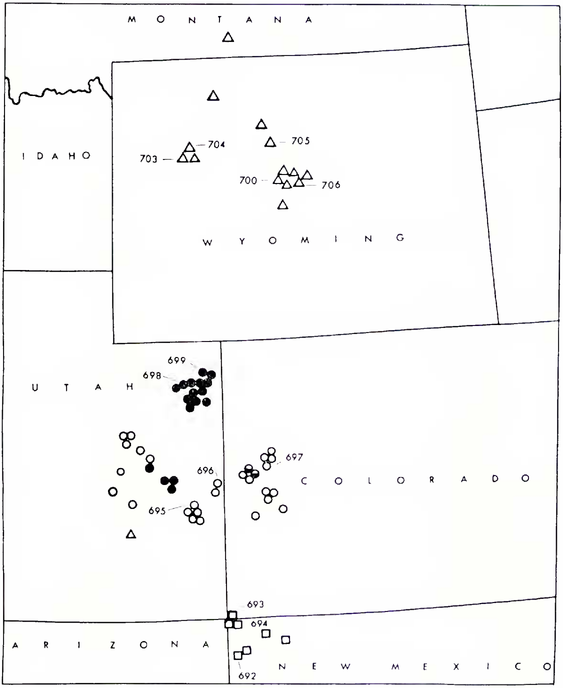
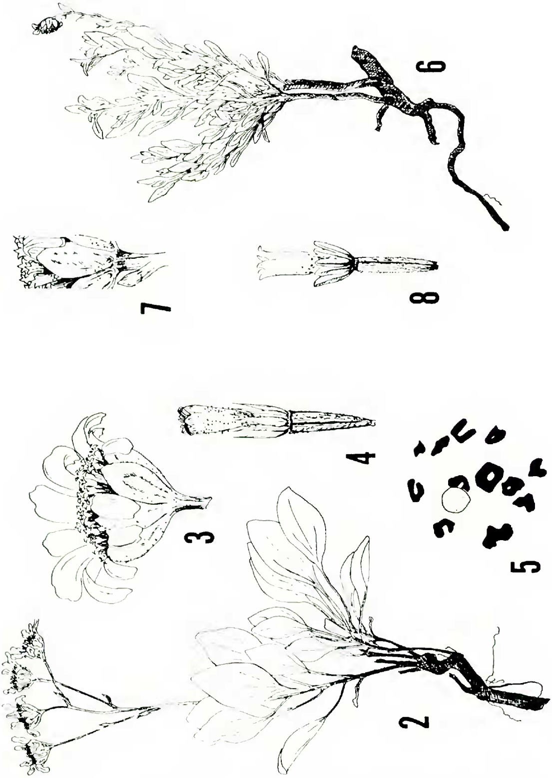
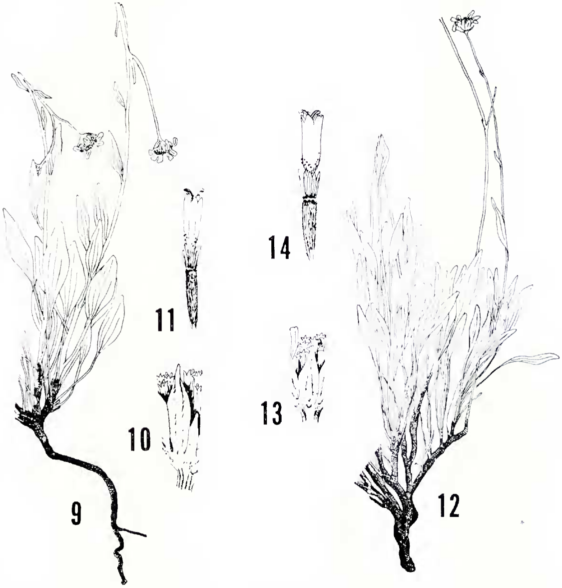


Fig. 1. Map showing distribution of the taxa under study. Taxon A, triangles; Taxon B, dots; Taxon C, circles; intermediates between taxa B and C, half-closed circles; Taxon D, squares. Numbers indicate locations of mass collections.



Figs. 2-8. Taxa A (Figs. 2-5) and D (Figs. 6-8). Habit, Figs. 2 & 6, X 0.5; head, Figs. 3 & 7 (part only), X 3.5; disc floret, Figs. 4 & 8, X 5; chromosomes in diakinesis, Fig. 5, X 1000.

The first beneficial result is that the students seem to finish the course with a higher level of understanding and appreciation for plant systematics than without employment of the case studies. The objectives of being able to recognize discontinuities in sets of comparative data and being able to evaluate these discontinuities with respect to the ranks of the taxonomic hierarchy are achieved in large measure for almost everyone in the class. The students gain first-hand experience in struggling to apply concepts of taxa and categories, and this seems to cement these concepts more firmly. The students also develop a more positive attitude toward plant systematics in general, perhaps due to a better understanding of the difficulties involved with making classifications.



Figs. 9-14. Taxa B (Figs. 9-11) and C (Figs. 12-14). Same scale and views as in Figs. 2-8.

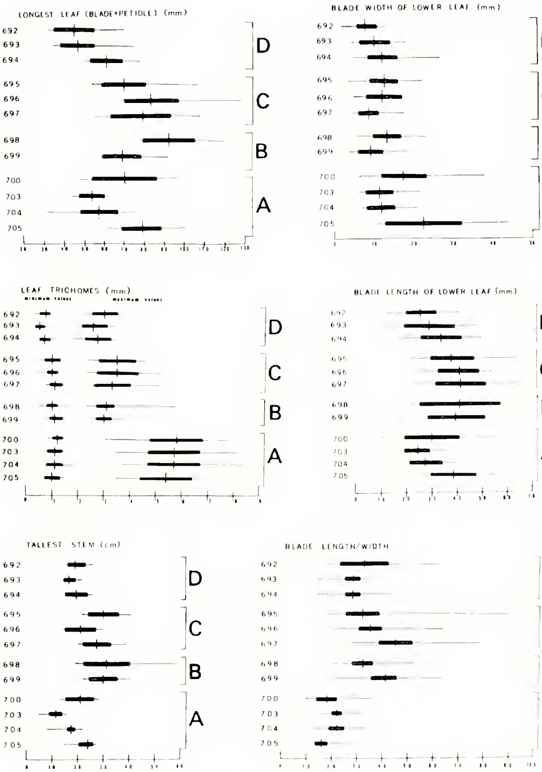


Fig. 15. Quantitative measurements of some characteristics of the four taxa (A-D) in this study. The range of variation observed is indicated by the length of the horizontal line. The resulting unweighted mean and twice the standard error are indicated by the vertical line and accompanying rectangle.

Table 1

Significant Comparative Morphological Characters of the Taxa under Study.

	Taxon A	Taxon B	Taxon C	Taxon D
stem leafiness	mostly basal or occasionally extending midway up stem	both basal & cauline, leaves extending up stem 15–60% of stem height	both basal & cauline, leaves extending 20–60% of stem height	mostly leafy to apex or rarely only midway
lower stem surface processes	glabrous to moderately pubescent w/few-numerous stipitate glands	lightly to heavily pubescent w/few globules of surface exudate	lightly to moderately pubescent w/stipitate glandulosity increasing markedly w/height	glabrous to heavily pubescent w/no-few short stipitate glands
upper stem surface processes	moderately pubescent w/few-numerous stipitate glands	lightly to heavily pubescent w/no-few stipitate glands	glabrous to moderately pubescent w/numerous stipitate glands	lightly to moderately pubescent w/no-few sessile or short stipitate glands
peduncles & bract surface processes	numerous short stipitate glands	no to moderate pubescence w/no-few sessile or short stipitate glands; occasionally glabrate	numerous stipitate glands	lightly to heavily pubescent w/few-numerous stipitate glands
petiole length (mm)	(3)12–45	(7)13–40	16–60	8–35
peduncle length (mm)	(2.5)8–55(65)	11–140	6–140	8–55(75)
bract apex	obtuse, acute	caudate-attenuate or cuspidate (rarely acuminate)	obtuse, acute	obtuse, acute, acuminate
number of disc florets	41–83	40–60	40–75	25–58
disc floret throat length (mm)	2.3–3.8	1.4–3.5	1.5–4.0	2.0–2.8
achene length (mm)	1.0–5.1	2.0–6.2	3.5–6.0(8.0)	3.0–4.6
pappus scale length (mm)	(0.6)1.0–3.2	0.7–3.2	0.7–3.7	1.0–2.4(2.8)

The second beneficial result of using case studies is the positive carry-over to other science courses, and especially to those in other areas of biology. The students gain a better appreciation of the utility of any man-made classification for both animate and inanimate objects. They also are much better prepared to make taxonomic decisions of their own or critically evaluate those of professional taxonomists in other courses that require such efforts (e.g., Introductory Microbiology, Survey of the Animal Kingdom). The students also develop increased proficiency in evaluating methods of data collection, synthesis, and display, which has strong carry-over to all other areas of science.

The third beneficial result of using case studies is the improved intellectual self-confidence that is generated within most students. Occasionally, of course, a student will remain confused and baffled throughout the entire course and will never really understand how to work the case studies; but this occurrence is rare. In general, the students gain much self-confidence in making taxonomic decisions as evidenced by their increasingly perceptive comments throughout the course. Perhaps even more important is that the students gain self-confidence in presenting and defending their own viewpoints before their peers. Sometimes, especially early in the term, the resultant student classifications are widely divergent, and this leads to lively and constructive discussion.

CONCLUSION

From my experience in using case studies in plant systematics courses, I firmly believe that they are an extremely valuable part of the curriculum. The case studies can be used at the undergraduate or graduate levels, with the complexity of the problems adjusted according to the backgrounds and abilities of the students involved. It may have been noticed that the previous section of the paper stressed only beneficial results of using case studies; this was done deliberately, because I believe no detrimental effects accrue, except for the loss of time that alternatively could have been spent on other topics.

Because it involves considerable efforts to extract and rearrange the data from original papers for class use as case studies, it might be worth mentioning that I have assembled a collection of case study examples and exercises for publication in the near future. Along with these case studies have been written several chapters that hopefully will provide at least an introduction to the concepts that are necessary for working effectively the exercises themselves.

ACKNOWLEDGMENTS

Sincerest thanks go to the numerous students who have offered criticisms in the development of the case study concept presented in this paper. Thanks are also due Dr. E. D. Rudolph for reading the final manuscript.

Costs associated with manuscript preparation and publication have been borne in part by NSF Grant GB-37678. Permission to reproduce figures and tables and to quote portions of the text in the case study used here from *Brittonia* has been granted generously by The New York Botanical Garden.